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Root and Rhizome Distribution as an Indicator of Upper Salt Marsh Wetland Limits

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Root and rhizome distribution as an indicator of upper salt marsh wetland limits

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Abstract

Four wetland plant species, *Deschampsia cespitosa, Distichlis spicata, Grindelia integrifolia,* and *Salicornia virginica*, were tested to determine the effect of soil moisture on the vertical distribution of roots and rhizomes. In an 8-month greenhouse experiment involving plants grown from seeds and rhizomes the occurrence of more than 65% of the root and rhizome mass in the upper 10 cm of soil was indicative of saturated conditions. Roots and rhizomes were more evenly distributed under field capacity and low moisture conditions. The percent of total root and rhizome biomass in the upper 10 cm of a 35 cm core may be useful in determining whether or not a plant is experiencing saturated soil conditions, a criterion often used for defining wetlands. Limited field studies support the conclusion of the greenhouse study.

Introduction

Field studies of underground biomass distribution of coastal salt marsh plants along the Atlantic coast of the United States have been conducted by Gallagher *et al.* (1977). Profile shape generally appeared to be species dependent, however, in the only case where they measured distribution for the same species in two different environmental situations they found two distinct types of profiles. Gallagher (1974) found that 69% of the underground biomass of high marsh *Spartina alterniflora* was located in the upper 15 cm of 35 cm cores. In similar cores taken of creekbank *S. alterniflora* only 44% of the underground biomass was located in the upper 15 cm. Perhaps the difference seen in root distribution of the two forms was due to differences in soil moisture and therefore soil aeration. Redox potentials, which decrease with increased waterlogging, were shown by Mendelssohn *et al.* (1981) to be greater in creekbank soil than in high marsh soil.

It was the purpose of this greenhouse study to ascertain whether or not root and rhizome distribution can be correlated to soil moisture. A correlation between root and rhizome distribution and soil moisture may be useful to regulating agencies having the responsibility of protecting wetlands. In the United States, regulations set forth by the U.S. Army Corps of Engineers define wetlands as 'those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalance of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.' (U.S. Army Corps of Engineers, 1981). In the field, this definition alone becomes inadequate.

Several approaches have been proposed to overcome this inadequacy in delineating wetlands, including the use of tidal datums or floristic criteria which bases wetland limits on the presence of certain indicator species (Frenkel *et al.* 1981). The use of tidal datums alone has proven to be unsuccessful and the time involved in assessing and evaluating a particular situation based on floristic criteria is long

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and evaluation often becomes quite complex, especially in areas where, depending on the slope of the land, wide zones take in large horizontal areas.

Physical criteria such as soil salinity and soil moisture form a possible base on which to define wetland limits. Salinity, however, varies diurnally, seasonally, and with depth and distance from the estuary mouth, and would therefore not provide consistent data. Soil moisture, used in the Corps of Engineers definition of a wetland, would seem to be a better basis for defining wetland limits, however, making the decision as to whether an area is wetland or upland cannot be based on soil moisture measurements made at a single point in time. High temporal variability caused by precipitation and tidal fluctuations would have to be overcome by taking many observations, a year's data may be required, with subsequent computation of frequency/duration values for selected zones in the marsh (Lewis & Liverman 1979). The necessity of such a long study would be impractical for the purpose of permit evaluation.

The above methods may not provide the precision necessary in highly populated areas where large sums of money are at stake when only a few feet of area are in dispute. In such areas, a very precise method for wetland limit determination becomes important. It may be necessary to draw a line within a zone of a single species. With respect to precise wetland delineation Seliskar (1981) has studied changes in plant morphological characteristics within a species along a soil moisture gradient.

If root distribution can be correlated with soil moisture, realizing that root growth would integrate the long-term effects of the total environment under which the plants are growing, then the determination of root distribution may provide a one-time measurement for use in delineating upper wetland limits. Since most of the wetland plants are perennial species the measurements could be made at any time of the year. One would not have to wait for peak summer growth.

Four salt marsh plant species were chosen for the study, *Deschampsia cespitosa*, a perennial, caespitose grass, *Distichlis spicata*, a perennial, rhizomatous grass, *Grindelia integrifolia*, a perennial composite, and *Salicornia virginica*, a perennial, rhizomatous succulent. Although seed and rhizome stocks were collected from an Oregon salt marsh these species were selected because of their wide geographic distribution, thereby making results of this study applicable to other areas. *D. spicata* and *S. virginica* can be found on both the Atlantic and Pacific coasts. The distribution of *D. cespitosa* includes Alaska to Greenland, most of the U.S., northern Mexico and Eurasia. *G. integrifolia* is distributed coastally from Alaska to northern California (Hitchcock & Cronquist, 1973).

Materials and methods

Plants were grown in pots 36 cm in height and 15 cm in diameter. These were constructed from PVC (polyvinyl chloride) irrigation pipe with an 18 cm^2 PVC plate cemented to the bottom of each. A 0.8 cm hole was drilled into each pot 0.5 cm above the base to allow drainage. For each species the pots were arranged on a greenhouse bench in a random block design with ten replicates of each moisture treatment.

The pots were filled to a depth of 35 cm with river sand (Barbour, pers. comm.). One fourth of the pots were planted with *D. cespitosa* seeds collected the previous fall from the marsh fringing Netarts Bay, Oregon. Rhizomes of *S. virginica* and *D. spicata* were collected at Netarts Bay, on the northern Oregon coast the day before planting, brought back to the greenhouse where they were washed free of mud with tap water and four, approximately equal size sections were placed in each of the respective pots. In the case of *G. integrifolia*, both seeds, collected the previous fall, and young plants collected at Netarts the day prior to planting were used. Thirty young *G. integrifolia* plants, each approximately 5 cm in height were sorted and one was placed in each pot. Seeds were then planted around the transplant.

The substrate surface of each pot was covered with 1 cm of peat to aid in maintaining moisture. To allow for germination and equilibration, the pots were watered with tap water every other day and with North Carolina State University (NCSU) nutrient solution (Downs & Hellmers 1975) once every two weeks.

After four weeks, the plants were watered with their appropriate concentrations of artificial seawater, Rila Marine Mix (Barbour 1978). In an attempt to duplicate natural field conditions, *G. integrifolia* and *D. cespitosa*, the upper marsh plants,

were kept at a constant salinity of 8‰ while *D. spicata* and *S. virginica*, from the lower marsh were maintained at 16‰ (Liverman, pers. comm.). These salinities were maintained throughout the experiment. Salinity of the interstitial water was measured with an American Optical refractometer (Behrens 1965).

Moisture treatments were begun at the start of the fifth week. All the pots were flushed with their appropriate concentration of seawater. Five hundred milliliters of the NCSU nutrient solution were then added to each pot and allowed to drain. At this point, the drainage holes in the saturated pots were stopped with rubber serum vial caps. Seawater was then added until saturation was reached, i.e., water was standing on the substrate surface. Water was maintained on the surface throughout the experiment except once a month when the pots were reflushed in the manner described above. The plants growing under saturated conditions were watered as needed with tap water to avoid the addition of more salts and to replace that water lost by evaporation.

In order to achieve field capacity conditions without the loss of nutrients due to the frequent watering of these plants, the field capacity pots were set up in a manner similar to that used by Parrondo *et al.* (1978). Each pot was placed on a 15 cm × 15 cm × 5 cm block of wood with a styrofoam cup positioned under the drainage hole of each. These plants were watered every other day with tap water after which the drained water was recycled by pouring it back into the top of the pot. Thus, the amount of nutrients and salts in all pots remained constant.

The plants under dry conditions were watered only frequently enough to keep the moisture level just above wilting point, which was determined by taking a soil core with a 10 cm^3 syringe from each of three random pots and calculating the percent moisture on a dry weight basis. When the moisture value reached approximately wilting point (3.8% moisture at 15 bars tension), as read from a moisture tension curve for the river sand, the plants were watered. Watering was necessary only about once a month and when this level was reached, all pots received a monthly reflushing. During the hottest summer weeks the greenhouse temperature rose above the usual 24 °C. At these times, it was necessary to give the dry condition plants a frequent sprinkling of tapwater to prevent wilting.

The experiment which began in March continued through mid-November 1979, with the four species being harvested at different times to allow time for the processing of samples: *S. virginica* - 2 Oct., *D. spicata* - 1 Oct., *G. integrifolia* - 30 Oct., *D. cespitosa* - 19 Nov. No thinning was performed during the study and stem density was significantly less in the dry treatment. Belowground biomass and its distribution were determined for each pot. Due to the variable sized sand particles and the presence of peat, a rather long and intricate method of washing was necessary. The pot was inverted and slipped off the soil column. The soil column was laid on its side and cut with a knife and/or scissors into sections, 0–10 cm, 10–20 cm, and 20–35 cm (or to pot bottom - not always 35 cm due to settling) from the soil surface.

The sections were washed individually. Each section was placed in a tub and covered with water; gentle shaking allowed the larger roots and rhizomes to come free of sand and peat. The remaining mixture of sand, roots, and water was poured into a 1.0 mm mesh sieve and washed with running water until all sand less than 1.0 mm in size was removed. The mixture left in the sieve was placed in a tub of water where the roots were picked out with forceps. The water and suspended material were then decanted into a sieve from which the remaining roots were collected. Roots and rhizomes from each step were combined, placed in aluminium foil boats and dried in a 60 °C oven. Statistical analysis included mean, standard deviation, one-way analysis of variance, and Student-Newman-Keuls (SNK) range test (Sokal & Rohlf 1969).

Field sampling in saturated soils was done in October 1982. Five cores, 3.5 cm in diameter and 35 cm in length, were taken from each of two sites in Delaware: 1) a natural *D. spicata* marsh shown in an earlier study to have standing water on the surface at low tide level for 13 of 15 sampling times during a one-year period (Gallagher 1971), and 2) an artifically created *D. spicata* marsh plot. The latter site had been flooded with seawater three times a week during the growing season for seven years. Live roots and rhizomes were separated from sectioned cores and dried in a 60 °C oven.

Results and discussion

Root and rhizome distribution in these species is definitely affected by variations in soil moisture. As can be seen in Table 1 (note that depths are arranged in order of increasing weights), under DRY (near wilting point) and under SAT (saturated) conditions most of the root mass was in the upper 10 cm. Roots and rhizomes were more evenly distributed in the FC (field capacity) treatment. In all cases, except for the FC treatment of *S. virginica*, there were significant differences between the various depths as shown by the SNK range test especially with the 0–10 cm section being significantly higher.

It is not surprising to find more even root and rhizome distribution under FC conditions. Table 1 contains the actual mean g dry weight values and shows where significant differences occur. Distribution can be easily viewed, however, in Fig. 1 as the percent of the total root biomass. Here, under the FC treatment, soil moisture is more evenly distributed as is oxygen, hence, field capacity offers optimal growth conditions for the plants.

The root and rhizome mass under DRY conditions is significantly greater in the upper 10 cm (Table 1). This is most likely due to the frequent sprinkling of water (without a complete flushing) given to prevent wilting during the hottest summer months. Thus with soil moisture greater near the surface root growth is also greater here.

For all four species under the SAT treatment by far the greatest percentage of root and rhizome mass occurred in the upper 10 cm of the soil column (Fig. 1), 93% in the case of *S. virginica*. As can be seen in Table 1 the root and rhizome mass at this depth for all species was significantly greater than at the other two depths. With all four species tested a 0–10 cm root and rhizome mass equalling 65% of the total root and rhizome biomass in a 35 cm core or greater is indicative of continually saturated soil conditions (Fig. 1).

Since such a large and significant percentage of the root and rhizome mass is located in the upper 10 cm of the soil column under saturated conditions, sampling wetland sites for root distribution would be an easy means of obtaining information on soil saturation for these species, i.e. whether or not plants in that area are subjected to saturated soil much of the time. With a coring device such as the one described by Gallagher (1974) sampling would be an easy task. One sampling would be necessary since root and rhizome growth would integrate soil moisture conditions over a period of time. If 65% or more of the root and rhizome biomass in a 35 cm core of *D. cespitosa, D. spicata, G. integrifolia*, or *S. virginica* occurs in the top 10 cm it could be considered to be indicative that the plants are experiencing continuous soil saturation.

The field sampling in wet *D. spicata* sites in Delaware verified the results found with that species in the greenhouse study. In the natural marsh 95.6% ±

Table 1. Root distribution. Depths are arranged in order of increasing weight. Underlined values are not significantly different from one another according to the SNK test, $\alpha = .05$. (DRY = near wilting point, FC = field capacity, SAT = saturated).

	DRY			FC			SAT		
Deschampsia cespitosa									
Depth (cm)	20–35	10–20	0–10	20–35	10–20	0–10	20–35	10–20	0–10
$\bar{X}$ (g dry wt)	0.3	0.5	1.1	1.3	1.7	3.3	0.2	1.0	3.1
SNK Test									
Distichlis spicata									
Depth (cm)	10–20	20–35	0–10	10–20	0–10	20–35	20–35	10–20	0–10
$\bar{X}$ (g dry wt)	2.8	4.1	5.0	7.1	8.4	9.8	1.7	3.0	9.7
SNK Test									
Grindelia integrifolia									
Depth (cm)	10–20	20–35	0–10	10–20	0–10	20–35	20–35	10–20	0–10
$\bar{X}$ (g dry wt)	1.9	2.0	2.8	4.8	6.1	8.0	0.1	1.6	5.9
SNK Test									
Salicornia virginica									
Depth (cm)	20–35	10–20	0–10	10–20	20–35	0–10	20–35	10–20	0–10
$\bar{X}$ (g dry wt)	0.4	0.8	1.9	1.4	1.8	3.3	0.03	0.13	2.3
SNK Test									

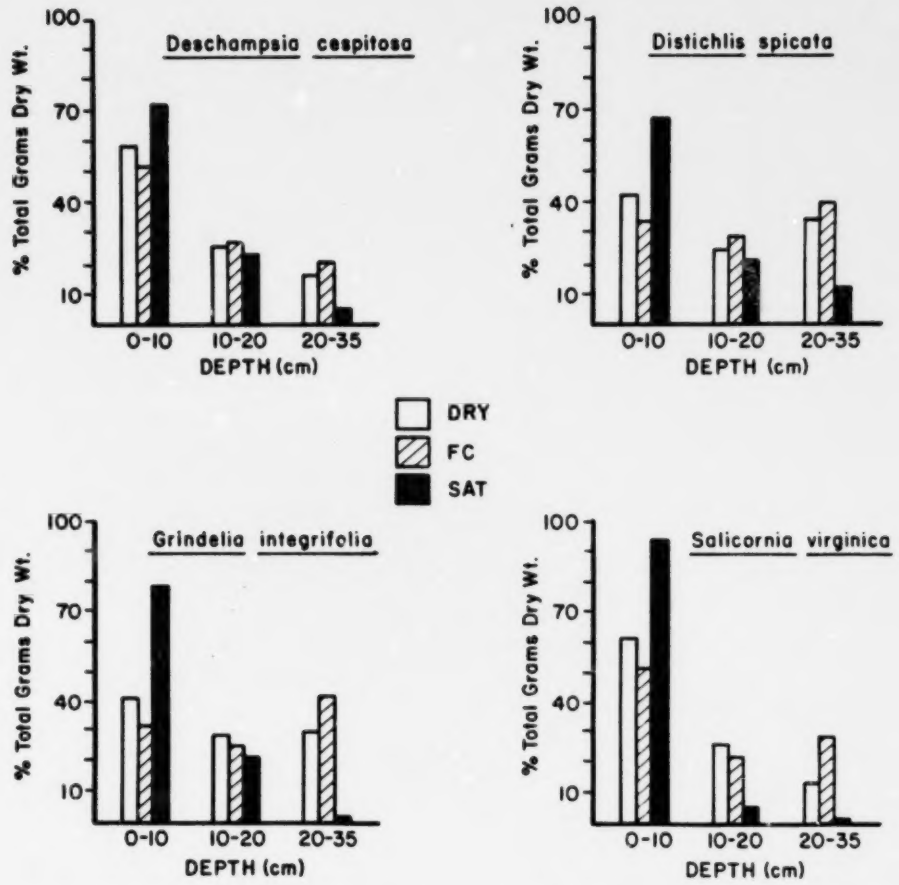

Fig. 1. Root biomass distribution measured as percent of total grams dry weight (Dry = near wilting point, FC = field capacity, SAT = saturated).

3.3% of the live root and rhizome biomass was present in the upper 10 cm of the soil column. In the artificial marsh plot 96.5% ± 1.9% of the live root and rhizome biomass was present in the upper 10 cm. These values are well within the proposed 65% limit indicating that these soils are frequently flooded, as they are known to be.

Further work needs to be conducted with respect to length of intervals of saturation and field verification. However, with the urgency of wetland protection and the need for defining wetland boundaries the simple procedure of a) taking a soil core (with replicates) in the field, b) sectioning it into 0–10, and 10–35 cm sections, c) washing the sections under water over a 1 mm sieve, and d) drying the root samples and determining the percent of total weight made up by the 0–10 cm section, may provide an aid for establishing the wetland limit more precisely.

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